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Report No. G-1245-01

FISCAL YEAR 1986 PROGRAM REPORT

Robert C. Stiefel
Director

United States
Geological Survey

State of Ohio
Water Resources Center
The Ohio State University

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Water Resources Center
The Ohio State University
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Robert C. Stiefel, Director

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ABSTRACT

Water is one of Ohio's most important natural resources, and the State has an adequate supply to meet its immediate needs. Most of Ohio's water problems are associated with water quality. Of primary concern are the sediments, nutrients and acids in the surface waters from urban, agricultural and mining areas. and the toxic and hazardous waters that threaten the ground and surface waters. The focus of the 86 State Water Research Program was directed at some of these needs. One project examined the simultaneous adsorption and biodegradation that occurs in a three-phase fluidized bed that utilizes immobilized living microorganisms in an aerobic wastewater treatment process. Another project studied the specific mechanisms that certain bacteria have developed to resist inhibition caused by Cadmium in the environment and to investigate the potential that these organisms have in the translocation of this highly toxic metal. A third project developed methodology to determine the impact that seasonal water usage has on the safe yield that can be provided from reservoirs used to supply municipal drinking water. The fourth project analyzed the risks and benefits that occur from disposing of oil and gas brines by injecting them in the annulus of producing oil and gas wells in the state. Training was provided through this program for nine students enrolled in five disciplines at two universities in the State.

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WATER PROBLEMS AND ISSUES OF OHIO

Water is one of Ohio's most important natural resources. Bounded on the north by Lake Erie and on the south by the Ohio River and containing other extensive ground and surface waters, Ohio has an adequate supply of water to meet its immediate needs. However, the combination of large, heavily industrialized urban centers; extensive agricultural activities; high volume coal production and large coal reserves; and the associated demands for new energy production continues to cause concerns related to water quality and water management. In addition, extreme hydrologic events cause localized problems of both excessive water and water deficiencies at times.

Surface Water

The northern 25 percent of Ohio's area drains into Lake Erie, while the southern portion drains into the Ohio River. Runoff from Ohio's streams and rivers averages about 25 billion gallons per day. The state also receives nearly a billion gallons of runoff daily which drains through the Maumee River to Lake Erie from the neighboring state of Indiana; and Ohio has access to additional flows past its boundaries in Lake Erie and the Ohio River that total well over 150 billion gallons of water per day.

Last year, over 16 billion gallons of water were withdrawn from Ohio's surface sources each day to meet the demands for municipal supplies; rural needs for domestic and livestock purposes; irrigation; and self-supplied industrial needs including cooling water for thermo- electric power generation. These demands account for only 60 percent of the available surface waters in the state's streams each day, and localized shortages only develop during certain dry seasons and periodic droughts.

The combined length of all the streams in Ohio approaches 44,000 miles, which means that there is approximately one mile of stream for each square mile of surface area in the state. In addition, there are more than 50,000 lakes, ponds and reservoirs within the state having a combined surface area of 200,000 acres. Only a small fraction of these, about 6,700 acres, occur naturally. The remainder are man-made impoundments that range in size from small farm ponds to large multipurpose reservoirs.

The reservoirs in the state are used to provide water for many different purposes including municipal, agricultural and industrial supplies; stream flow augmentation; flood control; and recreation. No impoundments in Ohio, other than those on the main stem of the Ohio River, provide water for downstream navigation or hydro-electric power generation. However, there is extensive navigation on both Lake Erie and the Ohio River, and consideration is being given to the installation of low-head hydro-electric generators at several developed dam sites throughout the state.

Flooding, still a major problem in Ohio, affects both urban and agricultural areas; and it has been estimated that nearly two million acres of land in Ohio are flood prone. This represents over seven percent of the total area of the state and includes nearly four percent of those areas classified as urban regions. Average annual flood damages in Ohio vary from year-to-year but amount to several millions of dollars annually.

Ground Water

Ground water is an important part of Ohio's water resources. Ground water underlies most of the state but is predominant in the glacial drift in the northwest, in the ice-contact and outwash deposits in river valleys along the border of the glaciated areas, and in the bedrock of the western portions of the state. Ground water supplies are largest in the glacial valley-train deposits in those drainage basins which border the Ohio River including the Ohio, Miami, Little Miami, Scioto, Hocking and Muskingum Rivers. Well yields from these deposits often exceed 500 gallons per minute (gpm), while aquifers in the glacial drift in the northwest and west-central parts of the state produce yields between 100 and 500 gpm. Isolated aquifers in the northeast, northwest and southwest have yields between 25 and 200 gpm, while much of the northeast contains aquifers whose yield is between 5 and 25 gpm. With the exception of the valleys along the major streams, most of the aquifers in the area that is tributary to the Ohio River have yields less than 5 gpm.

Three-quarters of Ohio's 650 public water supply systems use ground water as their source. In terms of volume withdrawn, however, a lesser share of these supplies comes from ground water, for only around a half billion gallons of ground water are withdrawn each day for public water supply purposes, while over one billion gallons come from surface water sources. However, ground water supplies nearly 80 percent of the rural water needs in Ohio, 32 percent of the irrigation waters and 21 percent of the industrial water demands. Nearly one billion gallons of ground water are withdrawn in the state each day to meet these needs.

Water Quality

It is the quality of water, rather than its quantity, that is the more critical and limiting condition associated with the use of both ground and surface waters in Ohio. The ground waters of the state frequently have relatively high, natural mineral contents; but, except for a few local areas, most of these waters are free from man-related contamination. Most complaints are related to increased levels of turbidity, bacterial populations and other substances from improperly sited or poorly constructed or maintained wells. Other problems are related to the spillage and leakage of brines and petroleum at oil wells in the southeastern part of the state; the mis-application of pesticides, herbicides and insecticides in agricultural areas; and the improper siting and operation of solid and liquid waste disposal facilities. Some minor ground water problems associated with the excessive use of highway de-icing salts or its improper storage have also been reported.

The dissolved solids concentrations in Ohio's streams range between 120 and 2,500 milligrams per liter (mg/l). The higher concentrations are found in the Tuscarawas, Cuyahoga and Grand Rivers and in other stream reaches below major municipal and industrial outfalls or in areas subjected to diffuse source runoff.

Of the 23,000 miles of the principal rivers downstream of major urban areas in the state that have been monitored 16,000 miles, or 70 per cent of these streams, meet the current water quality standards. Where problems do exist, they are frequently caused by inadequate municipal wastewater treatment at facilities that need be upgraded or expanded, or by combined sewer overflows. Substantial improvements in surface water quality have resulted from the development of pretreatment regulations for industrial waste discharges to municipal sewerage systems. Violations of the state's water quality standards occur most often in dissolved oxygen levels; ammonia nitrogen concentrations; the numbers of fecal coliforms; and the levels of heavy metals such as lead, zinc, and cadmium.

Acid mine drainage is a major cause of water quality problems throughout the Appalachian Coal Basin in the eastern United States. In Ohio this region extends in a band approximately 50 miles wide in a southwesterly direction from the east-central to the south-central parts of the state. Acid drainage from abandoned and improperly operated or reclaimed coal mined lands causes a loss of water for domestic and industrial uses; the degradation of water quality for recreational purposes; a lethal impact on the aquatic life in a stream; and an accelerated deterioration of highway and railroad bridges and electrical transmission lines and towers. Drainage from abandoned coal mines, both surface and underground, has impacted around 1,500 miles of streams in 27 counties in southeastern Ohio. Approximately 370,000 acres of abandoned strip mines, 7,000 acres of coal refuse piles and 3,000 underground mines are contributing to this problem. It has been estimated that four billion dollars would be needed to reclaim the abandoned mines and refuse piles throughout Ohio. Projected revenues from severance taxes earmarked for abandoned mine reclamation come to about ten million dollars annually. Obviously, the technologic problems and the economic costs associated with the control of acid mine drainage will continue to keep this a major problem of water quality in southeastern Ohio for years to come.

Little detailed information is available concerning the impacts that diffuse sources of pollution such as agricultural and urban stormwater drainage have on the quality of water in Ohio's inland streams. One concern with non-point pollution is the sediment that is dislodged from the land surface and carried to the streams. Of greater concern are the pollutants, such as the nutrients, heavy metals and toxic organic substances, that enter the streams attached to the sediments. No need for intensive, non-point source control programs to meet water quality standards in that area of the state that drains to the Ohio River has been shown; but several studies are underway in the Lake Erie drainage basin to define the role of agricultural drainage on the water quality in the lake. Much more research and many more demonstration projects on the best management practices for agriculture, silviculture, mining and urban runoff control must be conducted before this problem is fully understood and control measures can be instituted.

The trophic status of several lakes and reservoirs has been studied; and the results suggest that the lakes and reservoirs in the sandstone bedrock areas of the state have generally lower trophic levels than those in the limestone bedrock areas or glaciated regions. Water quality was generally good to excellent in most of the lakes and reservoirs surveyed. However, excessive concentrations of copper and other heavy metals, bacteria and other pollutants normally associated with urban activities were identified in some of the lakes.

Recent studies on Lake Erie indicate that there has been a reduction in several key pollutants and a gradual, but steady, improvement in the water quality in the Lake during the past few years. Phosphorus is a major pollutant which results in the excessive growth of algae and other aquatic plants. As these plants die and decay, they deplete the oxygen resources of the Lake. The construction of faciliites to remove phosphorus at those municipal wastewater treatment plants which discharge directly to Lake Erie has been a major factor in the reduction of phosphorus loadings and of the subsequent reduction of the anoxic areas within the Lake. Additional work on the control of phosphorus from both diffuse sources and point sources needs be accomplished, but a significant start has been made.

Levels of bacteria have been reduced in the nearshore zones where municipal wastewater treatment facilities have been constructed. This has permitted regulatory agencies to re-open bathing beaches which were often closed during the period between 1960 and 1970. Concentrations of mercury and pesticides have been reduced substantially, principally because of the federal bans that have been instituted on their manufacture, use and disposal. PCB remains a major challenge, as does the control of sediment and the nutrients, fertilizers and organic chemicals that are attached to it.

Fish populations, including the walleye pike, are beginning to increase again in the lake; but the quality and diversity of fish is still far from what they were in the past. Thermal pollution is a localized problem in some near-shore areas. However, as closed cycle cooling is required on all power generation facilities, the extent of this problem will diminish.

PROGRAM GOALS AND PRIORITIES

The Water Resources Center at The Ohio State University encourages and supports research that is directed at providing information needed to solve the major water problems at the local, state, regional and national levels. The research program at the Center includes basic or fundamental research, problem oriented or applied research, and information dissemination and technology transfer activities.

During FY 1982, the Center, in cooperation with several groups of water-related agencies and officials throughout the State prepared a prioritized list of Ohio's major water resources problems. Based upon this analysis, the following ranking of these problems was developed:

1. POLLUTION FROM DIFFUSE SOURCES - including agricultural runoff; urban runoff; runoff from on-site waste disposal systems; runoff from active, reclaimed or abandoned coal and strip mines.

2. CONTAMINATION OF DRINKING WATER SUPPLIES including surface and ground waters for both urban and rural uses by diffuse and point sources, and by the disposal of toxic and hazardous wastes on the land.

3. TOXIC AND HAZARDOUS WASTE DISPOSAL - including their control, treatment, disposal and impact upon land, water and air resources.

4. POLLUTION FROM POINT SOURCES - including municipal and industrial sources not yet in compliance with their NPDES permits.

5. IMPACTS OF FLOODING AND DRAINAGE - including flood damages, the use of flood plains and alternative structural and non-structural means of controlling floods and reducing flood damages.

6. IMPACTS OF WATER RESOURCES DEVELOPMENTS - including the impacts on various land uses caused by structural and non-structural water resources developments such as the extension of water mains and sewers into rural areas; flood control projects; hydro-electric power generation; water-based recreation; etc.

7. INSTREAM FLOWS NEEDS - including interrelationships among water quality, water quantity and land use practices on the instream flow needs for fish, wildlife, and recreation and the optimum development and protection of these instream uses.

8. IMPACTS OF SYNTHETIC FUEL DEVELOPMENT - including requirements for water and impacts of the disposal of wastes from these processes into waters and onto the land.

9. IMPACTS OF ATMOSPHERIC POLLUTION - including the effects of acid precipitation and atmospheric fallout on water quality and the environment.

10. ALLOCATION OF WATER RESOURCES- including the development of contingency plans for the allocation and conservation of limited water supplies among competing water users during periods of low stream flows.

Subsequently, the Directors of the Water Resources Research Institutes in the Great Lakes, Upper Mississippi and Ohio River Basin's met to identify from their State problems the major water resources research priorities for the

Region. A listing of these priorities is included at the end of this Section of this Report.

The focus of the 1986 State Water Resources Research Program was primarily directed at some of these critical needs. The research and technology transfer program consisted of the following activities:

The project by L. S. Fan entitled "Simultaneous Adsorption and Biodegradation in a Three-Phase Fluidized Bed with Immobilized Living Cells for Aerobic Wastewater Treatment" contributed to the knowledge of the intrinsic rate of biodegradation that can be developed in a biofilm that contained immobilized, living cells and explored the simultaneous effects that adsorption and desorption had on the overall biodegradation rate in the biofloc. This wastewater treatment process is felt to be a substantial evolution in the operational technology of bioreactor design; and the successful completion of this project could result in the development of an innovative, reliable and considerably less costly wastewater treatment system.

The project entitle "Cadmium Assimilation by Lake Sediment Bacteria" studied the specific mechanisms that certain sediment bacteria have developed to resist inhibition by Cadmium and determined the potential role that these organisms have in the translocation of this highly toxic metal in the environment. Information obtained on the bacterial strains isolated during this study will aid in the development of genetically engineered bacteria for the treatment of wastewater containing high levels of Cadmium and other toxic metals, The project entitled "Effect of Seasonal Water Usage Variations Upon reservoir Safe Yield", characterized the seasonal fluctuations in the demand for water in community water supply systems and developed a methodology to determine the effect that these variations have on the calculation of the safe yield that can be provided from a surface water supply reservoir.

The project by Drs. Hobbs and Haimes at the Case Western Reserve University entitled "Risk-Benefit Analysis of Annular Disposal of Oil and Gas Brines" examined the risks and the benefits of this method of brine disposal and compared it with deep well injection. Ohio is the only state which still permits the controversial practice of disposal of oil and gas well brines by injecting them back into the annulus of the production well. Recent legislation permitting annular disposal in Ohio will probably be reviewed in the next few years, and the results of this study could affect the decision to continue the practice of annular brine disposal.

Training on these research projects was provided to a post-Ph.D. student, three doctoral students, and two graduate students in the disciplines of Chemical Engineering, Civil Engineering, Natural Resources, Water Resources Systems Engineering and Environmental Microbiology. In addition, three undergraduate students in Microbiology gained practical knowledge and experience by working on these projects.

The technology transfer programs of the Water Resources Center continue to disseminate information about the water resources of Ohio to the local and state decision-makers, and provides technical assistance to help resolve some of the state's major water problems.

Regional Research Priorities
Great Lakes - Upper Mississippi - Ohio River Region

A. Groundwater contamination

1. Track pollutants through the vadose zone to the groundwater and determine their rate of dissipation in the aquifer.

2. Assess the impacts of the disposal of municipal and industrial wastes and effluents on groundwater systems.

3. Evaluate sources of recharge of the principal aquifers in the region.

4. Determine the effects of the storage of waste heat in aquifers on groundwater quality.

B. Pollution of lakes and streams from non-point sources

1. Assess relative effectiveness of non-point pollution control "best management practices" to meet the demands of P.L. 92-500.

2. Evaluate the effects of atmospheric fallout and precipitation (acids, toxic metals and hazardous trace organics) on public health and the aquatic environment.

3. Estimate the effects of drainage from land use activities in urban areas on surface water quality.

4. Model sediment transport processes and devise techniques for determining sediment delivery ratios.

5. Determine the relative effectiveness of voluntary programs enhanced by various incentives and regulation as mechanisms of implementing non-point pollution control.

6. Predict the impacts that agricultural technologies will have on surface and groundwater resources.

C. Adverse water resources impacts of energy production and mining.

1. Evaluate the impacts that drainage from mining activities will have on the incursion of acids, toxic metals, radio nuclides and hazardous organic compounds into the environment.

2. Assess atmospheric and aquatic pollution from coal-fired electric generation plants.

3. Assess legal, economic, environmental and social impacts and develop means for resolving water user conflicts associated with siting, constructing and operating energy conversion facilities and mining operations.

4. Examine the potential benefits, public and environmental, from the reclamation of heated waters from power generation.

D. Potential insufficiency of waters for agriculture and rural communities

1. Determine optimal water requirements for crop production and develop practical methods for irrigation scheduling.

2. Evaluate criteria for establishing minimum requirements for the drainage of imperfectly drained soils of the region.

3. Develop water conservation practices and methods for holding and temporarily storing surface and drainage waters for reuse in periods of seasonal suboptimal precipitation.

E. Loss and degradation of water based fish and wildlife habitat

1. Define the functional and economic value of wetlands including ecological and hydrological mechanisms that influence their integrity.

2. Develop acceptable mechanisms, including incentives and legislation, for preserving publicly and privately owned wetlands.

3. Determine the quality and quantity of instream flow necessary to maintain an active and viable aquatic biota.

4. Determine the potential and incentives needed to increase wildlife and waterfowl production on private lands.

F. Miscellaneous

Develop the relationship between commercial/commodity and recreational use of the major lake and river systems of the region. Research emphasis should be placed on development of sufficient water-based recreational facilities in urban settings.

Synopsis

Project Number: 02

Start: 07/85
End: 06/87

Title: Simultaneous Adsorption and Biodegradation in a Three-phase Fluidized Bed with Immobilized Living Cells for Aerobic Wastewater Treatment

Investigator: Fan, Liang-Shih, Department of Chemical Engineering, The Ohio State University, Columbus

COWRR: 05D

Congressional District: Fifteenth

Descriptors: fluidized bed process, biological wastewater treatment, phenols, draft tube, kinetics, adsorption.

Problem and research objectives:

The ability of fluidized bed bioreactors to outperform other reactor configurations in aerobic biological wastewater treatment including trickling filters, activated sludge systems, and rotating drum contactors has been demonstrated, but when traditional physical removal processes are coupled with biological degradation processes the wastewater treatment process becomes more effective.

This study investigated the intrinsic characteristics of and the interaction between the adsorption/desorption of biodegradable pollutants by activated carbon particles and the biodegradation kinetics of the biofilms attached to the surface of the activated carbon particles. Phenolic compounds were selected as the model biodegradable pollutants for this study. They are the major pollutants in wastewater discharged from the coal conversion process and the EPA strictly regulates their concentration levels in surface water. In the first year of this project, the fundamental transport and bio-kinetic phenomena of the integrated adsorption-biodegradation process were independently evaluated. Studying the transient behavior resulting from the interaction of adsorption and biodegradation when the process was exposed to step changes in pollutant loadings was the second year's research.

Methodology:

Activated carbon particles were immobilized with cells of a mixed culture and operated for phenol removal in a 5.1 liter draft tube three-phase fluidized bed bioreactor (DTFB) for periods of one to three months. In the transient phenol degradation experiments, the immobilized cell particles from the 5.1 liter reactor were cultivated in a one liter DTFB under preset operating conditions until a steady state was reached. Step increases in influent phenol concentrations, 40 percent, 100 percent, and 200 percent were added to the DTFB, and the changes of bulk phenol concentration were monitored. The biofilm properties at the initial and final steady states were also determined. A mathematical model was developed which incorporated the reactor hydrodynamics, the bio-kinetics, the physical adsorption capacities of the activated carbon and the time-delay effect of microbial cells to substrate loadings. Computer simulation illustrated the relative merits of the adsorption/desorption and biodegradation to the overall phenol removal rates.

Principal findings and significance:

When a 40 percent step increase of influent concentration of phenol was added to the DTFB the biofilm thickness and dry density remained approximately the same at both the initial and new steady states. When a 100 percent step increase of influent phenol concentration was added to two systems having approximately the same biofilm properties but different influent phenol concentrations, the system with the higher inlet phenol concentration showed higher transient changes and required a longer time to resume a new steady state. These findings suggest that systems with lower substrate inlet concentrations exhibit greater stability when exposed to step change in substrate loading. A 200 percent step increase in inlet concentration created a drastic transient change. The system stabilized within 30 hours and no instability corresponding to wash-out in freely suspended cell systems occurred.

A comprehensive mathematical model, which considers the external mass transfer resistance, simultaneous diffusion, biodegradation, adsorption/desorption of phenol and oxygen, and the time-delay effect of microbial growth during the transient period was used. In the first year of this project the biological and physico-chemical parameters in the model were independently evaluated. These parameters included the diffusivity of phenol within the biofilms, the adsorption isotherm of phenol on virgin and spent activated carbon particles, and the intrinsic kinetics of phenol biodegradation by the mixed culture. The results of the computer simulation show adsorption of phenol by the core carbon particles is crucial to the present system in order to rapidly respond to the substrate shock loading and to rapidly restore steady state operation. The results predicted from the model show reasonable agreement with the experimental data when the time delay mechanism of microbial cells is incorporated.

Publications and professional presentations:

Tang, W. T., K. Wisecarver, and L.-S. Fan, "Dynamics of a Draft Tube Gas-Liquid-Solid Fluidized Bed Bioreactor for Phenol Degradation," Chem. Eng. Sci., in press (1987).

L.-S. Fan, K. Fujie, T-R Long, and W. T. Tang, "Characteristics of a Draft Tube Gas-Liquid-Solid Fluidized Bed Bioreactor with Immobilized Living Cells for Phenol Degradation," Biotechnol. Bioeng., in press (1987).

Tong, C.-C., and L.-S. Fan, "Concentration Multiplicity in a Draft Tube Fluidized Bed Bioreactor," Biotechnol. Bioeng., in press (1987).

Wisecarver, K., and L.-S. Fan, "Biological Phenol Degradation in a Gas-Liquid-Solid Fluidized Bed Bioreactor," to be presented at the AIChE Annual Meeting at New York, Nov. 15-20, 1987.

Tang, W. T. and L.-S. Fan, "Simultaneous Adsorption and Biodegration of Organic Substrate Using Activcated Carbon Particles with Immobilized Living Cells: Experiments, Modeling and Simulation," AIChE J., 33 2) 239-249 (1987).

M. S. theses

None

Ph. D. dissertations

Wisecarver, K. "Characterization and Modeling of Gas-Liquid-Solid Fluidized Bed Bioreactor,", 1987.

Synopsis

Project Number: 03 — Start: 07/86, End: 06/87

Title: Cadmium Assimilation by Lake Sediment Bacteria

Investigator: Pfister, Robert M., Department of Microbiology, The Ohio State University, Columbus

COWRR: 05B — Congressional District: Fifteenth

Descriptors: cadmium assimilation, sediment bacteria, aquatic environment, Lake Erie

Problem and research objectives:

Microbial assimilation of dissolved metal ions can result in the conversion of soluble metal to particulate form. Such conversion can dramatically alter both the dynamics of metal cycling in the environment and the availability of metals to other life forms. The primary objective of this research was to determine the potential role of bacteria in the translocation of the toxic metal cadmium in Lake Erie sediments. In addition, the effects of pH, temperature and elevated levels of NTA, EDTA as well as other metal ions on Cd accumulation by sediment isolates were determined. A secondary objective of this research was to determine the effects of Cd pollution on bacterial density and diversity in Lake Erie sediments. This information will contribute significantly to an understanding of the impact of Cd on the role of microorganisms in the environment and the potential contribution of bacteria to the translocation of this toxic metal in Lake Erie sediments.

Methodology:

To determine the potential for selected isolates to accumulate Cd from lake water under simulated environmental conditions, six isolates from Cuyahoga River sediments were selected to be analyzed for their ability to accumulate Cd from filter sterilized lake water. The six isolates used in this study were selected based on their resistance to Cd and their relative ability to accumulate the metal during exposure to Cd in tryptone broth (TB). The selected isolates were chosen to represent both Cd-resistant and Cd-sensitive bacteria that demonstrated either low or high level uptake of Cd in TB.

Principal findings and significance:

Cuyahoga River isolates MC102 (*Bacillus* sp.) and MC107 (*Proteus* sp.) were chosen for analysis in lake water because cells of these isolates accumulated the most Cd of all the gram-positive and gram-negative Cd-sensitive isolates from Cuyahoga River sediments that were tested. When compared to controls (no cells), the concentration of Cd that remained dissolved in lake water was reduced from 1.0 ppm to 0.31 and 0.45 ppm by MC102 and MC107 cells respectively. The reduction in dissolved Cd could in both instances be accounted for by the cell associated Cd that could be removed by centrifugation of aliquots from the cell suspensions. These results suggest that in a dilute aqueous environment, Cd-sensitive isolates have the potential to remove dissolved Cd from solution, thereby reducing the concentration of dissolved Cd in the water column and potentially increasing the concentration of Cd in sediments inhabited by these isolates.

Cadmium accumulation by MC315 (Alcaligenes sp.) cells (a Cd-resistant isolate that demonstrated relatively low level Cd uptake in TB) was lower than for MC102 or MC107 cells. The amount of dissolved Cd remaining in lake water with MC315 cells suspended in it was higher than the amount remaining in lake water containing MC102 or MC107 cells as a result of decreased accumulation of the metal by MC315 cells.

Isolate MC215 (Klebsiella sp.) was selected for analysis in lake water because it accumulated the highest level of Cd from TB when compared to other Cd-resistance isolates. The increased Cd accumulation by MC215 cells corresponded with a decrease in the concentration of dissolved Cd remaining in lake water when compared to the final concentration of dissolved Cd obtained by the other Cd-resistant isolates.

Isolate MC103 (Proteus sp.) was selected for analysis in lake water because of all the Cd-sensitive bacteria isolated, this organism demonstrated the lowest level of Cd accumulation from TB. Cadmium accumulation by MC103 cells was lower than that of MC107 cells (the other Cd-sensitive isolates studied in lake water). These results were consistent with the relative Cd uptake demonstrated by each of the Cd-sensitive isolates in TB. However, long term exposure to the metal in lake water resulted in cellular accumulation of Cd by MC103 cells that nearly equalled that observed from the other Cd-sensitive isolates that accumulated high levels of Cd from TB.

Cadmium uptake from lake water by cells of the 5 sediment isolates that were tested in each case was greater than the amount accumulated by the same isolates in TB (Table 1). The consistent trend of increased accumulation by isolates in lake water probably reflects differences in time of exposure and concentration of Cd used in the two experiments. Nevertheless, the amount of Cd taken up by isolates in lake water reflected the relative uptake by these same bacteria in TB. That is, similar to results in TB, the Cd-resistant MC315 cells accumulated less Cd from lake water than did the Cd sensitive MC102 and MC107 cells. Cadmium uptake from lake water by MC215 cells, which were Cd-resistant, despite their relatively high level of Cd uptake in TB, was higher than the level observed for Cd-resistant MC315 cells which were comparatively low level accumulators. Finally, Cd uptake from lake water by Cd-sensitive MC103 cells that demonstrated a relatively low level of Cd uptake in TB, was lower than uptake by the other Cd-sensitive cells that were tested during the first 10 hours of incubation in lake water. However, by the end of

22 hours of incubation, Cd accumulation by MC103 cells had reached approximately the same levels observed for the other Cd-sensitive cells that had demonstrated relatively high levels of Cd uptake in TB (Table 1).

Table 1 Cd Uptake by Selected Sediment Isolates

		nmole Cd/mg cells (Dry weight)	
Isolate	Cd Resistance	Tryptone Broth [(a)]	Lake Water [(b)]
MC103	S	0.030	52
MC102	S	0.838	61
MC107	S	1.090	54
MC215	R	0.279	34
MC315	R	0.022	18

S = No growth in presence of 15 ppm Cd
R = Growth in presence of 15 ppm Cd
a - Cells exposed to 1 μM Cd for 5 minutes
b - Cells exposed to 17.8 μM Cd for 22 hours

These results suggest that measurement of Cd uptake in TB may be a good indicator of the relative level of Cd that will be accumulated from lake water by Cd-resistant and Cd-sensitive sediment bacteria that demonstrated relatively high levels of Cd uptake and for Cd-resistant bacteria that demonstrated relatively low levels of Cd accumulation. Results of this study also indicate that both Cd-sensitive and Cd-resistant bacteria can accumulate Cd from lake water, thereby removing it from the water column and concentrating it in the particulate fraction of the sediments. The process of Cd accumulation could effectively lower the concentration of dissolved Cd in overlying water. However, just as important is the implication that Cd uptake by sediment bacteria could lower the concentration of Cd in the pore water of sediments.

The dry weight of bacteria used in the lake water studies ranged from 0.16 to 0.23 mg./mL and the viable count of bacteria ranged from 10^5 to 10^8 colony forming units/mL which is well within the range of total aerobic heterotrophic bacteria found in fresh water sediments. Thus, these results indicate that both Cd-sensitive and Cd-resistant sediment bacteria can potentially alter the toxicity and availability of polluting Cd^{2+} by removing it from overlying waters and sequestering it in the sediments even in the absence of other sediment constituents that can sequester the metal. Furthermore, these studies indicate that sediment bacteria could effectively remove Cd from the pore water of sediments which could reduce the availability of the metal to both microorganisms and macroorganisms inhabiting the sediments. On the other hand, Cd exposure to those organisms that feed on bacteria in the sediments would be increased.

As sediment bacteria were shown to accumulate and retain Cd during ca. 22 hours of exposure in lake water, it is possible that bacterial communities in sediments could act as a secondary source of Cd pollution in aquatic environments. That is, Cd that was initially sequestered by sediment bacteria could possibly recontaminate the pore water and overlying waters of an aquatic ecosystem if conditions in the sediments were altered in a way that would cause the cells to release the metal. For example, the rapid infusion of a contaminant which either lysed bacteria or caused them to release intracellular Cd could cause an increase in the concentration of dissolved Cd in pore water or the overlying water column. The limits of such secondary contamination as well as the physical and chemical factors that might cause the release of cell-associated Cd must be studied before the potential role of bacterial communities in the recontamination of aquatic environments with accumulated metal can be predicted.

Publications and professional presentations:

Burke, B. E. , and R. M. Pfister. The Ohio ASM Annual Meeting, Delaware, Ohio, 1986. Cadmium Assimilation by Lake Sediment Bacteria.

Burke, B. E., and R. M. Pfister. The ASM Annual Meeting, Atlanta, GA, 1987. Cadmium Assimilation by Bacteria Isolated from Cd-Enriched and Comparatively Cd-Free Sediments.

Burke, B. E., 1987, Ph. D. Dissertation. The Ohio State University. "Cadmium Uptake and Resistance Among Selected Bacteria."

Burke, B. E., and R. M. Pfister. 1986. Cadmium Transport by a Cd^{2+-} Sensitive and a Cd^{2+-} Resistant strain of *Bacillus subtilis*. Can. Journ. Bacteriol., in press.

Burke, B. E., and R. M. Pfister. 1986. "Cadmium Resistance and Accumulation by Selected Lake Sediment Bacteria." Abs. Annual Meeting of the American Society for Microbiology.

M. S. theses:

None

Ph. D. dissertations:

Burke, B. E., 1987, Ph. D. Dissertation. The Ohio State University. "Cadmium Uptake and Resistance Among Selected Bacteria."

Synopsis

Project Number: 04 | Start: 07/86
End: 06/87 (expected)

Title: Effect of Seasonal Water Usage Variations Upon Reservoir Safe Yield

Principal Investigator: Whitlatch, E. E., Civil Engineering Department, The Ohio State University, Columbus

COWRR Category: 06D   Congressional District: Fifteenth

Descriptors: water demands, simulation analysis, time series analysis, municipal water, safe yield, Ohio

Problem and research objectives:

Every municipality, rural community or agricultural water user served by a surface water source must obtain an accurate estimate of the amount of water that it can safely withdraw. This estimated value is called the safe yield of the system, and is usually expressed as the rate of constant withdrawal that will cause a water supply shortage to be expected only once in a given number of years (usually 50 years). The assumption that safe yield can be based upon a constant water usage throughout the year may not be justified, and may result in substantial overestimation.

State-of-the-art methods, however, have not been applied systematically to determine the extent of seasonal (monthly) fluctuations in water usage, or the effect of such fluctuations upon statistical safe yield estimates. Therefore, it is necessary to recognize and deal with these seasonal fluctuations when statistically computing water supply safe yields.

The objectives of the research are (1) to obtain seasonal water use data for communities in Ohio that would be representative of the State, and to summarize and perform statistical tests upon this data in a manner so as to typify the underlying seasonal variability; (2) to develop synthetic data generation scheme(s) that would capture the fundamental statistical nature of the seasonal water usage data; and (3) to jointly simulate seasonal water usage and streamflow so as to derive statistical estimates of safe yield under the expected range of seasonal water usage fluctuations. Results can then be presented in a manner showing the expected influence of seasonal fluctuations on safe yield.

Methodology:

In the first stage, a letter and questionnaire were sent to all water systems in Ohio with capacities of one million gallons per day (MGD) or more, requesting monthly finished (treated) water use data. Phone follow-up and some site visits were also used to encourage response to the request. Data for those systems providing at least 20 years of record were analyzed to determine the extent of the seasonal variation in water use. Monthly indices of seasonal water use, as well as single-valued measures, were derived. Possible explanatory variables were tested through regression analysis to determine the cause of the seasonal component. The second stage of the study (not yet completed) is the derivation of statistical factors, based upon the monthly water use data, that would allow synthetic generation of water use data. Three possible generation schemes are envisioned: one is the disaggregation process; the second and third approaches are the ARMA and ARIMA models. Detrending is common to both the ARMA and ARIMA procedures, but the deseasonalizing step is conducted differently in the two. The ARIMA approach uses cyclic, and perhaps non-cyclic, differencing to achieve stationarity while the ARMA approach utilizes a variety of mathematical measures in an attempt to avoid the differencing step. In the third stage, generated monthly use and streamflow will be combined in a simulation environment and statistical results will be summarized. The streamflow generator found adequate and most conservative will be utilized. The combined usage-streamflow safe yield analysis can be parameterized over the range of seasonal fluctuations found in the data, and over selected ratios of total annual usage to total annual inflow. Results will be compared to safe yield estimates found assuming no seasonal fluctuations.

Principal findings and significance:

Data were solicited from 162 water suppliers in Ohio with demand of one MGD or more, and responses were received from 72. Of these, 28 systems provided at least 20 years of monthly water use data, and these systems are listed in Table 1. Analysis of these data in stage one of the project revealed that (1) seasonality of water use in Ohio is not as extreme as that reported in the literature for the Washington, D. C. water system, (2) the average 'fraction seasonal' water use for the Ohio systems surveyed was 0.09, based upon a 3-month winter season, (3) there is wide variability in the seasonal component among the systems analyzed, (4) the single most influential factor determining seasonality is the 'user ratio', defined as the percentage of residential water use divided by the percentage of industrial water use (seasonality increases with an increased percentage of residential water use and decreases with an increased percentage of industrial water use), (5) system size, while statistically significant, is a minor determinant of seasonality (seasonality decreases slightly as system size increases), (6) whether a system has a declining block rate or uniform rate structure has no effect on seasonality (the increasing block rate structure was not sufficiently represented in the data to draw any conclusions on its effect), and (7) source of water (surface or groundwater) does not affect seasonality for the systems analyzed.

These findings are significant in that seasonality and its possible causes have never been studied before on such an extensive cross-sectional and longitudinal data base. Stages two and three of the study are currently underway.

Table 1. Water Systems Included in the Study

System Name	Years of Data	System Name	Years of Data
Akron	26	Lakewood	26
Belmont County	20	Lorain	25
Berea	28	Mahoning Valley	29
Canton	20	Mansfield	25
Cincinnati	23	Martins Ferry	30
Cleveland	24	Miamisburg	20
Cleveland Heights	30	Montgomery County	25
Columbus	29	Norwalk	27
Delaware	27	Piqua	20
Elyria	25	St. Mary's	24
Erie County	29	Sidney	20
Galion	37	Toledo	30
Greenville	24	Warren	27
Hamilton	25	Westerville	33

Publications and professional presentations:

Whitlatch, E. E., and Thomas M. Liggett, "Seasonality Indices for Monthly Water Use in Ohio" (to be submitted to Water Resources Bulletin, August, 1987).

MS thesis:

None

Ph. D. dissertations:

None to date (1 Ph. D. participant)

Synopsis

Project Number 05 Start: 07/85
End: 06/87

Title: Risk-Benefit Analysis of Annular Disposal of Oil and Gas Brines

Investigators: Hobbs, Benjamin F. and Haimes, Yacov Y., Case Western Reserve University, Cleveland

COWRR: 06B Congressional District: Twenty-first

Descriptors: risk-benefit analysis, brine disposal, waste disposal wells, input-output analysis, oil and gas industry, groundwater, economics

Problem and research objectives:

Brine wastes from oil and gas production in Ohio have contaminated surface and ground water supplies. A controversial disposal method allowed in Ohio is annular disposal. This practice deposits brine into the annulus of the production well and provides only one or two barriers between the brine and fresh water aquifers. Deepwell injection, an alternative disposal method, provides at least three barriers between the brine and the aquifers.

The major objective of the research was to investigate the risks and benefits of permitting annular disposal. The risks are the health and financial costs resulting from possible groundwater contamination. The benefits are 1) the avoided costs of deep well injection and 2) the secondary benefits of employment and taxes from a financially healthier Ohio oil and gas industry. A second objective is to create a convenient computerized methodology for evaluating the risks of underground waste disposal in particular regions.

Methodology:

The research consisted of five tasks:

1. Estimating the frequency and severity of brine leaks from annular disposal wells by statistical analysis of actual well test data.

2. Calibrating and applying solute transport models to fresh water aquifers in regions where annular disposal is used.

3. Estimating the probability of contamination to water supply wells of towns and rural homes by using probabilistic models of brine spills and water well location.

4. Estimating the benefits of annular disposal using engineering economics, econometrics, and input-output analysis.

5. Comparing the risks and benefits of increased annular well inspection and of banning annular disposal in Ohio.

The two products from this research are an assessment of risks and benefits of annular disposal in two study regions in Ohio and the development of a computerized methodology which allows government or private users to perform tasks 2 and 3 for other areas.

Principal findings and significance:

Task 1: Estimation of Annulus Reliability. The probability of failure of annular disposal wells was estimated using data obtained from the Louisiana Bureau of Conservation, Division of Injection and Mining. The data are primarily annual radioactive tracer surveys for determining the mechanical integrity of wells.

Two probabilities were estimated from the test results:

p = the probability of immediate failure due to faulty installation of the production casing; and

q = the probability per year of well failure following well completion

These were estimated by maximum likelihood analysis, using a reduced gradient non-linear programming method. The resulting probabilities of failure are $p = 0.0025$ and $q = 0.009/\text{yr}$. Based on the asymptotic properties of maximum likelihood estimators, the standard deviation of q is 0.002.

Typical values of brine loss in Louisiana, given a failure of the annulus, were found to be between 5 percent and 20 percent of the amount injected.

Tasks 2 and 3: Calibration of the Solute Transport Model and Estimation of the Risks of Water Supply Contamination. For the second task, a personal computer compatible model was designed to analyze the potential impact of annular well failure on the surrounding population. The model, "Risk Impact from Solute Contamination" or "RISC", is designed to help decision makers choose inspection frequencies and safe disposal locations. It also aids in evaluating the merits of annular disposal as a brine disposal option.

The model considers both solute transport and impact upon water wells. It explicitly includes probability distributions of: a) leaks of disposal wells of varying durations (until detected and shut down); b) leaks of different magnitudes (based on disposal rates, percent leakage, and chemical composition); and c) water well locations. The model can also consider various contaminants, inspection frequencies, and well lifetimes.

Implementation consists of two stages. The first stage simulates the aquifer response to a slug of contaminant to derive an impulse response function. This stage uses the USGS Method of Characteristics model of 2-dimensional solute transport.

The second stage uses the impulse response function to analyze the impact on water wells within the study area. RISC addresses the question: "What is the probability that N municipal or private water wells will be contaminated, given the aquifer parameters, number of disposal wells, probabililty of disposal well failure, probability distributions for brine disposal rates, and the chemical make-up of the brine?"

These models were applied to two aquifers which represented a range of geohydrologic conditions. Most of the geohydrologic parameters for these sites were obtained from field studies. The Black Hand sandstone has meager water well yields and slow groundwater velocities. The Muskingum river valley has very productive wells and high flow rates.

The risks are stated in terms of the number of water wells contaminated during 20 years of annular disposal. The analysis showed that sodium and benzene would cause the most contamination, as defined by drinking water standards. The approximately 700 annular disposal wells in the Black Hand sandstone region are expected to contaminate 2.5 rural home water wells by annular disposal well leakage. There is also a two percent chance of contaminating a community well field, and a four percent chance of contaminating five or more rural home supplies. In the buried valley region, annular wells are expected to contaminate one home well and have a one percent probability of contaminating a town's well field. These calculations are based on an annular well inspection frequency of once every five years and presume a 20 year life-time for a typical annular disposal well.

Task 4. Estimation of benefits. The benefits of annular disposal were calculated by comparing the cost to the alternative method of deep well injection, and then estimating the effect on the oil and gas industry and the state's economy to impose that cost.

Based on estimated deep well disposal costs of $1.50/bbl, a ban on annular disposal wells would impose an immediate direct cost to Ohio oil and gas producers of $2,200,000/year, assuming that no annular wells are shut down.

Econometric models of drilling and production activity were estimated. The drilling models related drilling rates compared to past drilling rates, and to the projected worth of present drilling activity in the six most important counties having annular disposal wells. The production models regressed production rates upon past production rates, new wells drilled, and price.

A ban on annular disposal would affect drilling by lowering the present worth of new wells and would affect production by lowering the effective price received by drillers. The analysis showed that a ban would lower drilling rates in Ohio by approximately 15 wells a year (less than 0.5 percent of the 1985 drilling rate). Future production would decrease by perhaps 90,000 bbl/year of oil and 600,000 mcf/year of natural gas. These figures are based on an assumed price of $20/bbl for oil, $3.10/mcf for gas, and a three percent real interest rate. The impacts are insensitive to price, but do vary somewhat with the assumed interest rate.

Drilling and production decreases would affect regional economic activity and employment. Based on this information and on an input-output model designed for southeastern Ohio, the long run annual direct and indirect economic impacts of a ban indicates a loss of about 80 jobs, $7,500,000 of regional output, and $1,100,000 of income (profit and royalties). This assumes a mean oil well cost of $100,000/well.

Task 5. Comparing the risks and benefits. In the Black Hand sandstone region increasing the inspections from once every five years to annual inspections for the next 20 years would increase inspection costs by $650,000 a year; but would only decreased the expected residential contamination by one well for the 20 year period.

The direct benefits of annular disposal in the Black Hand sandstone and buried valley regions are roughly $400,000/ year in terms of avoided disposal costs. By assessing a home at $60,000 and assuming the replacement cost for a municipal water supply at $200,000, the annual financial cost of contamination is approximately one order of magnitude less than the direct benefits of annular disposal.

The cost to attain zero risk does not appear to justify the benefits in either region. If annual disposal wells were permitted and the oil and gas industry was required to compensate all victims for contamination, both the industry and water well owners would be as well off financially as under a ban. Nevertheless, a ban on annual disposal may be desirable on public health or policy grounds.

This study did not address the public health aspects of the problem. This research assumed contaminated water wells were shut down and the only impact of groundwater contamination was the loss of water supply wells. It disregarded possible groundwater contamination impacts on fish and wildlife.

Publications and professional presentations:

C. V. Patterson, B. F. Hobbs, M. E. Maciejowski, and Y. Y. Haimes, "Annular Disposal Oil and Gas Brines in Ohio: A Risk Analysis," in S. J. Nix and P. E. Black, eds., Symposium on Monitoring, Modeling, and Mediating Water Quality, American Water Resources Association, May, 1987, 493-508.

B. F. Hobbs, C. V. Patterson, M. E. Maciejowski, and Y. Y. Haimes, "Risk Assessment of Annular Disposal of Oil and Gas Brines," American Geophysical Union Fall Meeting, Dec. 11, 1986.

B. F. Hobbs, J. Heslin, C. V. Patterson, M. E. Maciejowski, and Y. Y. Haimes, "Risk Benefit Analysis of Annular Disposal of Oil and Gas Brines," 14th Annual Water Resources Planning and Management Conference (ASCE), Kansas City, March 18, 1987.

M. S. thesis:

"Risk Analysis of Annular Disposal of Oil and Gas Brines," Carl-von Patterson, Case Western Reserve University, Cleveland, OH, January 1987.

Ph. D. dissertations:

None

INFORMATION TRANSFER ACTIVITIES

A series of five tasks were continued or initiated to transfer and disseminate information developed by researchers affiliated with the Water Resources Center to a wide range of State, Federal, County and Municipal agencies; to the private sector; to the academic community and to private citizens throughout Ohio.

Water Information Seminar

The Water Resources Center and the District Office of the Water Resources Division of the U. S. Geological Services jointly planned and sponsored a Water Information Seminar on Urban Runoff and Modeling on July 1, 1986 at the Fawcett Center for Tomorrow, the university's continuing education facility. The program was well attended and well received.

An outline of the topics and speakers presented at this one-day seminar follows:

Urban Storm Water Investigations by the U. S. Geological Survey
By: Marshall E. Jennings, Hydrologist Urban Hydrology Studies Coordinator for U.S.Geological Survey, Office of Surface Water, NSTL, MS

Estimating Flood Characteristics of Small Urban Streams in Ohio
By: James M. Sherwood, Hydrologist Water Resources Division, U.S. Geological Survey, Columbus

Estimating Biological Impacts Due to Increased Storm Water Runoff in Urban Streams
By: Andrew C. Vidra, III, Senior Environmental Planner, Northeast Ohio Area Coordinating Agency, Cleveland

Pleasant Run -- A Case Study
By: James L. Rozelle, General Manager and Chief Engineer, Miami Conservancy District, Dayton

State Standards for Urban Storm Water Management
By: Robert L. Goettemoeller, Chief, Division of Water, Ohio Department of Natural Resources, Columbus

Storm Water Management in Worthington, Ohio
By: Donald Mares, Project Engineer, Burgess & Niple Limited,

Undergraduate Use of Computer Models
By: Robert C. Stiefel, Professor of Civil Engineering, The Ohio State University, Columbus

The New Jackson Pike Water Treatment Plant for the City of Columbus
By: Robert M. Sykes, Professor of Civil Engineering, The Ohio State University

Ohio Water Resources Directories

The Water Resources Center is planning the development and distribution of a directory of the scientific expertise available in all areas of water resources research at the Universities within the State of Ohio. A questionnaire has been prepared and will be distributed shortly to all the researchers and research administrators at the forty-two Universities and colleges that are known to have demonstrated expertise in some field of water resources research. Key personnel at these Universities will be asked to circulate the questionnaires on their own campus to develop a wide response, but we are not planning on a program of extensive follow-up calls to attract responses. When the questionnaires are returned to the Water Resources Center, the information will be keyed into our computer, and the final directory will be prepared. Funds from the cooperating Universities and from the State water related agencies will be sought to help defray the costs of publication and distribution.

When the questionnaires are returned to the Water Resources Center, the information will be keyed into our computer and the final directory will be prepared. Funds will be sought from the State water related agencies and the Universities to help defray the costs of publication and distribution of this directory.

Water Luncheon Seminars

The Water Resources Center continued to co-sponsor a bi-monthly Water Luncheon Seminar Program for the water resources community in Central Ohio. This program, which was developed cooperatively with The Ohio Department of Natural Resources (ODNR), the Ohio Environmental Protection Agency (OEPA), the Soil Conservation Service (SCS), the District Office of the United States Geological Survey (USGS), and the Agricultural Engineering Cooperative Extension Service of The Ohio State University, continues to attract around seventy water resources professionals from Federal, State, County and Municipal Agencies, the private sector and the academic community to a forum to discuss current state, federal and local water policy issues, problems, programs and research results. In addition to providing speakers for one meeting a year, the Water Resources Center maintains the mailing list and produces and distributes the announcements for this program.

Listed below are the speakers and their topics that were presented during this year's meetings.

Water Luncheon Seminar, FY 1986

Date	Speaker/(Sponsoring Agency)	Topic
9/9/86	David Lightle, Agronomist Soil Conservation Service (Soil Conservation Service)	Animal Waste Distribution and Plant Nutrients
11/4/86	Julie Weatherington-Rice Consulting Geologist (Ohio Environmental Protection Agency)	The Governor's Oil & Gas Regulatory Review Commission
1/13/87	Rep. David Hartley, 62nd Ohio Dist. Chairman of House Agriculture & Natural Resources Committee (Ohio Department of Natural Resources)	Water Related Legislation Expected Before 117th Ohio General Assembly
3/10/87	Chris Yoder, Surface Water Section Ohio Environmental Protection Agency (Co-Sponsored by Ohio Biological Survey, The Water Resources Center and OSU Agriculture Extension Office)	Surface Water Pollution: How Do We Measure it?
5/12/87	J. T. Massey-Norton, Geotechnical Engineering Section of American Electric Power Company (Ohio District USGS Office)	Site Evaluation of Ohio's First Synthetically Lined Flue Gas Desulfurization Waste Landfill at Coshocton, Ohio

Consultation and Collaboration Activities

The Center's Director has continued to meet with the leading water resources officials in the state for the purposes of consultation and collaboration to identify the major water problems and the research needs of the state and region; to share information on current water management and policy issues; to seek continued support for our water research program and to disseminate the information and technology developed through this program and others at the universities throughout the State and Region.

The Director is the Lead Delegate to the Universities Council on Water Resources (UCOWR) and is a past member of the Board of Directors; he is a Past-Chairman of the National Association of Water Institute Directors (NAWID); he serves on the Water Programs Public Advisory Group to the Ohio Environmental Protection Agency and is a member of the Toxics Technical Advisory Committee; and he is a member of the Ohio Inter-Agency Water-Use Data Coordinating Committee for the Ohio District of the U. S. Geological Survey.

In addition to these activities, the Director has assisted in developing the organization of the newly created International Center for Water Resources Management at Central State University, a historically black university.

The Ohio State University recently became a Charter Member of the newly formed Ohio River Basin Research and Education Consortium, and the Director has served as a member of the Board of Trustees of that organization since November, 1985.

The Director has also been recently appointed by the Governor of the State to serve on the Ohio Water Advisory Council, a statutory commission that advises the Water Division of the Ohio Department of Natural Resources.

Water Resources Center Library

The Water Resources Center has maintained a library of water resources related publications since its establishment in 1965. Recently, the Center's holdings were merged with those of the Center for Lake Erie Area Research (CLEAR). The Water Resources Center provided the space for this merged library while CLEAR provided the staff to catalogue the material. This year the Water Resources Center also provided support for the operation of the library.

COOPERATIVE ARRANGEMENTS

Program Development

All four of the research projects that were initiated in the FY 1985 State Water Resources Research Program were continued in the FY 1986 Program. Because of the initial uncertainty in the authorized level of the Federal budget for this Program, the Water Resources Center's Advisory Committee felt it would be inappropriate to request new project proposals fro the FY 1986 Program. Therefore, no new proposals were solicited. A letter was sent to research administrators and qualified faculty investigators at over forty public and private colleges throughout Ohio, including Central State University and Wilberforce University, the two historically black universities in the State, indicating this fact and suggesting alternative sources of funds for the support of water related research.

The Ohio State Legislature did provide special funding this biennium for the development of an "International Water Resources Center" at Central State University. The Ohio State University has pledged to assist in the planning and development of this Program, and several Departments and Programs are providing expertise to the consultants and the faculty and administration at Central State. The Director of the Water Resources Center arranged a meeting between the consultants and the International Office of the USGS, for example, and has attended and participated in several planning meetings with the administration and the faculty at CSU.

A call for pre-proposals for the Fiscal Year 1985 State Water Resources Research Program was sent to research administrators and qualified faculty investigators at over 40 private and public colleges and universities throughout Ohio on December 1, 1984. This announcement contained the research priorities identified for the major water problems in the Great Lakes, Upper Mississippi and Ohio River Basins by the Water Resources Research Institutes in the Region.

The announcement also required interested researchers to request a copy of the Preliminary Proposal Application Form which was to be completed and returned to the Water Resources Center in mid-January, 1985.

The completed distribution list for this mailing contained over 250 names. In addition to this general mailing, separate letters were sent to the Presidents of the two historically black universities in the State, encouraging them to have their faculty participate in the Program.

Preliminary Proposal Application Forms were requested by and sent to thirty-two investigators and research administrators at fourteen colleges and universities in Ohio. However, no Historically Black University responded.

Evaluation/Selection Procedures

Twenty-one pre-proposals from seven universities and colleges throughout the state were submitted for evaluation and consideration. These pre-proposals were subjected to a review by all of the members of the Water Resources Center's Advisory Committee. In addition, the twenty-one pre-proposals were distributed to the various divisions within the three principal state and federal water-related agencies in the State by the representatives of these agencies who serve on the Advisory Committee, requesting that the divisions review the proposals. The three agencies included in this evaluation were the Ohio Department of Natural Resources, the Ohio Environmental Protection Agency, and the District Office of the United States Geological Survey.

The results of these reviews were presented at a meeting of the Advisory Committee where this panel selected seven of the pre-proposals and instructed the Center's Director to request fully developed proposals from the investigators for the Committee's further consideration. All seven of the selected pre-proposals were developed more fully and were re-submitted for consideration. The proposals were subjected to a technical review by at least three qualified evaluators selected by individual members of the Water Resources Center's Advisory Committee. Many of these evaluators were from state and federal agencies and from universities other than The Ohio State University.

The results of these reviews were presented at a meeting of the Advisory Committee and this panel ranked all seven of the proposals in the order they felt would best meet the needs and objectives of the Water Resources Center's program. The Advisory Committee then instructed the Center's Director to incorporate the four highest ranked proposals into the FY 1985 Program, and to develop a project for information transfer for the Center.

The membership of the Water Resources Center's Advisory Committee which includes representatives from five colleges and eleven departments of The Ohio State University and the three representatives of the principal water-related state and federal agencies, is included at the end of this section of the report.

Regional Cooperative Initiatives

The four projects selected for this program were compared with the FY 1985 Program synopses of the projects included in the programs of the other Water Resources Institutes in the Great Lakes, Upper Mississippi and Ohio River Basin to ensure that there was no duplication of efforts in the Region's research programs.

Program Management

At least once each quarter, the Director contacts the Principal Investigator on each research and information transfer project to discuss progress made during the quarter and to discuss the next quarter's plan of activities. At this same meeting budget details are reviewed and discussed, and necessary operating and reporting procedures to the Water Resources Center and to the Ohio State University Sponsored Research Administration are described.

Progress Reports or Completion Reports were prepared for each project by the Principal Investigators and were used by the Program Director to prepare the Program Final Report.

All of our investigators are urged to publish the results of their findings in the technical literature of their major disciplines and in other journals that are appropriate to the topic of their research. They are also encouraged and invited to present their findings at the Water Luncheon Seminar that is a part of the technology transfer activities of the Center.

The manuscripts that constitute the project completion reports are first reviewed by the Director of the Water Resources Center. As needed, the Director seeks the advice and council of appropriate state, federal and university scientists for methods of enhancing the value of the technical completion reports to the water-related community in the state and in the region.

TRAINING ACCOMPLISHMENTS

The following tabulation shows, by fields of study and training levels indicated, the numbers of individuals participating in projects that were financed in part with this grant.

Training Category		Training Level			
		Graduate			
	Undergraduate*	Master's Degree	Ph.D. Degree	Post - Ph.D.*	Total
Microbiology	3		1		4
Natural Resources		1			1
Engineering					
Chemical			1	1	2
Civil			1		1
Systems		1			1
	3	2	3	1	9